Korean Journal Of Agricultural Science
pISSN : 2466-2402
eISSN : 2466-2410

ANIMAL

Effects of non-genetically modified organism wheat-based diets on growth performance, nutrient digestibility, blood profile, and meat quality in grower-finisher pigs

Huan Wang[1], Dae Won Kim[1], Jong Sang Yoo[2], In Ho Kim[1,*]
[1]Department of Animal Resource & Science, Dankook University, Cheonan 31116, Korea
[2]Daehan Feed Co., Ltd, Incheon 22300, Korea

[*]Corresponding author: inhokim@dankook.ac.kr

Abstract

This study was conducted to determine the effects of dietary non-genetically modified organism (non-GMO) wheat-based diets on the growth performance, nutrient digestibility, blood profile and meat quality of grower-finisher pigs. A total of 70 [(Landrace × Yorkshire) × Duroc] growing pigs with an initial body weight of 26.15 ± 1.57 kg were used in a 112 day trial. The dietary treatments were as follows: (I) CD, corn-based diet and (II) non-GMO WD, a non-genetically modified organism wheat-based diet. Each treatment consisted of 7 replicate pens with 5 pigs per pen. In the current study, the pigs fed the corn-based diet had a higher body weight than the pigs fed the non-GMO wheat-based diet at day 21 and day 77 ($p < 0.05$). There was a significant difference in the average daily gain (ADG) during the first 21 days ($p < 0.05$). The non-GMO wheat-based diet had no effect on nutrient digestibility. In addition, the non-GMO wheat-based diet had no effect on the blood profile except for blood urea nitrogen (BUN) at d 21. In conclusion, the non-GMO wheat-based diet only had a slight effect on the growth performance of growing pigs but had no significant impact on the nutrient digestibility, fecal score, blood profile and meat quality of the pigs during the grower-finisher period.

Keywords: growing-finishing pigs, growth performance, non-genetically modified organism wheat

Citation: Wang H, Kim DW, Yoo JS, Kim IH. 2019. Effects of non-genetically modified organism wheat-based diets on growth performance, nutrient digestibility, blood profile, and meat quality in grower-finisher pigs. Korean Journal of Agricultural Science 46:705-713. https://doi.org/10.7744/kjoas.20190037

Received: July 18, 2018

Revised: July 03, 2019

Accepted: July 08, 2019

Introduction

With the continuous development of animal husbandry, the world pig production in the past few decades have risen to about 1.2 billion heads. Due to increased demand for corn, and changes in the price of corn on the international market, alternative low cost feed ingredient such as wheat is being researched as a source of energy as well as other nutrients to replace certain amount of corn in the diet.

Wheat is one of the most important agricultural products in the world and produced in many parts of the world (Carré et al., 2007). Due to wheat, generally lower cost per megajoule of digestible energy and its relatively high protein content in comparison to other grains, more attentions have been paid to the wheat. It has a feeding value of approximately 92% of corn for pigs (Hancock et al., 1993). Like most other vegetable feed ingredients, it is not a good source of P because most of its P is bound to phytic acid (PA), which is poorly digested by pigs (Bedford, 2000). Moreover, the higher content of non-starch polysaccharides (NSP) in wheat affects the digestion and absorption of wheat nutrients (Woyengo and Nyachoti, 2011). There have been some studies investigating enzyme supplementation and particle size of wheat in diets of pigs (Mavromichalis et al., 2000). As genetically modified (GM) crops pose a potential environmental, ecological, and human risk, many countries that use wheat as their main staple have opposed to the promotion of GM wheat (Quist and Chapela, 2001; Hanson et al., 2005).

The objective of the experiments reported herein was to investigate the effect of non-GMO wheat-based diet on growth performance, nutrient digestibility, blood profile, and meat quality in grower-finisher pigs.

Materials and Methods

The experimental protocols describing the management and care of animals was reviewed and approved by the Animal Care and Use Committee of Dankook University, South Korea.

Experimental design, animals, and diets

A total of 70 growing pigs [(Landrace × Yorkshire) × Duroc; 26.15 ± 1.57 kg] were used in a 112 days trial to evaluate the growth performance, nutrient digestibility, fecal score, blood profile and meat quality. Dietary treatments included: CD, corn-based diet; non-GMO WD, non-genetically modified organism wheat-based diet. Each treatment consisted of 7 replicate pens with 5 pigs per pen. The diets were formulated to meet or exceed NRC (2012) recommendations for all nutrients (Table 1). Pigs were housed in an environmentally controlled facility with slatted plastic flooring and a mechanical ventilation system. Each pen was equipped with a single face self-feeder and a nipple drinker to allow the pigs *ad libitum* access to feed and water throughout the experimental period.

Sampling and measurements

The live body weight (BW) of each individual pig was measured at the beginning and end (112 days) of the experimental period. Feed consumption was also recorded and gain/feed ratio was calculated on a pen basis.

Individual pig's BW was checked at the d 21, 42, 77, and 112, and the feed consumption was recorded per pen during the experiment to calculate the average daily gain (ADG), average daily feed intake (ADFI), and gain/feed (F/G) ratio.

During d 21 to 27, d 42 to 48 and d 112 to 118, chromium oxide (Cr_2O_3) was added to the diets as an indigestible marker at 0.20% of the diet to measure digestibility. Fresh fecal grab samples were obtained from at least two pigs in each pen at d 27, 48, and 118 to determine the apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N) and gross energy (GE). All fecal and feed samples were stored at - 20℃ until analysis. Prior to chemical analysis, the fecal samples were thawed and dried for 72 h at 60℃, after which they were ground to pass through a 1 mm screen. The feed and fecal samples were analyzed for DM, N, and GE according to AOAC (2000). Chromium was analyzed by UV absorption spectrophotometry (Shimadzu, UV-1201, Kyoto, Japan) following the method described by Yin and Kim (2019).

Table 1. Composition of the experimental growing-finishing pig diets (as-fed basis).

Items	Grower		Finisher	
	CD	Non-GMO WD	CD	Non-GMO WD
Ingredients (%)				
Corn	53.7	-	56.6	-
Wheat	5.0	-	5.0	-
Non-GMO wheat	-	62.4	-	67.4
Rice bran	-	5.0	-	1.0
Soybean meal	26.5	-	21.0	-
Canola meal	2.0	10.0	3.0	10.0
Corn gluten	-	4.0	-	3.0
Sesame meal	-	5.0	-	5.0
DDGS	1.5	-	2.0	-
Palm kernel meal	0.5	5.0	1.5	5.0
Fish meal	-	2.0	-	1.0
Meat meal	1.5	-	1.0	-
Soy oil	2.9	2.5	4.0	3.7
Molasses	3.0	-	0.3	-
Limestone	0.8	0.8	0.7	0.7
Calcium phosphate	0.6	0.4	0.5	0.6
Salt	0.3	0.3	0.3	0.3
Methionine	0.1	-	-	-
Lysine	0.6	1.0	0.4	0.9
Threonine	-	0.2	-	0.1
Tryptophan	-	0.4	-	0.3
Premix[y, z]	1.0	1.0	1.0	1.0
Calculated composition (%)				
ME (kcal/kg)	3,380	3,380	3,430	3,430
Protein	18.5	18.3	16.7	16.7
Fat	5.6	6.7	6.9	7.3
Fiber	3.0	4.0	3.2	4.8
Ash	5.3	4.7	5.0	4.4
Ca	0.65	0.65	0.57	0.57
P	0.55	0.55	0.48	0.48
Lysine	1.20	1.20	1.00	1.00

CD, corn-based diet; Non-GMO WD, non-genetic ally modified organism wheat-based diet; DDGS, dried distillers grains with solubles; ME, metabolic energy.

[y] Provided per kilogram of complete diet: vitamin A, 10,000 IU; vitamin D3, 2,000 IU; vitamin E, 48 IU; vitamin K3, 1.5 mg; riboflavin, 6 mg; niacin, 40 mg; d-pantothen ic, 17 mg; biotin, 0.2 mg; folic acid, 2 mg; choline, 166 mg; vitamin B6, 2 mg; and vitamin B12, 28 μg.

[z] Provided per kilogram of complete diet: Fe (as $FeSO_4 \cdot 7H_2O$) , 90 mg; Cu (as $CuSO_4 \cdot 5H_2O$) , 15 mg; Zn (as $ZnSO_4$), 50 mg; Mn (as MnO_2), 54 mg; I (as KI), 0.99 mg; and Se (as $Na_2SeO_3 \cdot 5H_2O$), 0.25 mg.

Two pigs were selected randomly from each pen (one barrow and one gilt) and blood samples were collected by anterior vena cava puncture on d 21, 42, 77, and 112. Blood samples were collected in 5 mL vacuum tube (Becton Dickinson Vacutainer System, Franklin Lakes, USA) and then centrifuged (3000 × g, 15 min, 4℃) within one hour after the collection of the sample to separate the serum. The protein, blood urea nitrogen (BUN), creatinine, and glucose in the serum samples were analyzed with an automatic biochemical analyzer (HITACHI 747, Japan) using colorimetric methods.

At the end of the experiment, two pigs (1 barrow and 1 gilt) per replicate pen per treatment were randomly selected and slaughtered at local commercial slaughter house. Carcasses were placed in a conventional chiller at 4℃. After chilling at 4℃ for at least 24 h, piece of the right loin sample was removed between the 10th and 11th ribs. The meat samples were thawed at room temperature before evaluation. Sensory evaluation was conducted by six trained panelists to evaluate the colour darkness, firmness and marbling of fresh loin samples using a five-point assessment scheme according to the procedures established by the NPPC (2000). Immediately after the subjective tests were conducted, meat colour of the longissimus muscle (LM) as lightness (L^*), redness (a^*), and yellowness (b^*), was determined using a Minolta chromameter (Model CR-410, Minolta Co., Japan) to evaluate the freshly cut surface after 30 min of blooming at 4℃. At the same time, duplicate pH values of each sample were directly measured using a pH meter (Model 77p, Istek, Seoul, Korea). Water-holding capacity (WHC) was measured using methods of Kauffman et al. (1986). The areas of pressed sample and expressed moisture were delineated and determined with a digitizing area-line sensor (MT-10S; M. T. Precision Co., Ltd., 123 Tokyo, Japan). A ratio of water area: meat area was calculated to give a measure of WHC, with smaller ratio indicating higher WHC and is termed as ‘expressed juice percentage’. LM area was measured by tracing the LM surface at 10th rib, which also used the above-mentioned digitizing area-line sensor.

Cook loss was determined as described previously by Sullivan et al. (2007). Drip loss was measured using approximately 2 g of meat sample at d 1, 3, 5 and 7 after slaughter according to the plastic bag method described by Honikel et al. (1986).

Statistical analysis

All data were subjected to the statistical analysis as a randomized complete block design using the general linear model procedures of SAS (SAS Inst., Inc., Cary, USA), and the pen was used as the experimental unit. The initial BW was used as a covariate for the ADFI and ADG. Differences among all treatments were separated by using the Tukey’s test. A probability level of $p < 0.05$ was considered to be statistically significant.

Results

Growth performance and nutrient digestibility

The growth performance and nutrient digestibility are shown in Tables 2 and 3. In the current study, CD had higher body weight than pigs fed non-GMO WD in d 21 and 77 ($p < 0.05$). There was a significant difference in average daily gain (ADG) at 0 - 21 days ($p < 0.05$). However, the ADFI and feed conversion ratio (FCR) in the pigs fed non-GMO wheat-based diet were comparable with those fed control diets. In addition, there were no differences in overall ADG, ADFI, and FCR in non GMO group compared with control (Table 2). Non-GMO wheat-based diet showed comparable ($p > 0.05$) nutrient digestibility compared with corn-based diet (Table 3).

Table 2. Effect of dietary non-GMO feed supplementation on growth performance in growing-finishing pig.

Items	CD	Non-GMO WD	SEM	p-value
Body Weight (kg)				
Initial	26.15	26.14	0.02	0.808
Day 21	38.93	38.32	0.17	0.042
Day 42	54.27	52.95	0.42	0.065
Day 77	81.54	79.54	0.53	0.036
Day 112	111.3	108.64	0.96	0.097
Day 0 - 21				
ADG	608	580	8	0.047
ADFI	1,318	1,293	24	0.501
FCR	2.132	2.196	0.040	0.370
Day 22 - 42				
ADG	730	697	16	0.197
ADFI	1,674	1,659	29	0.346
FCR	2.311	2.384	0.080	0.350
Day 43 - 77				
ADG	799	760	14	0.360
ADFI	2,424	2,342	41	0.201
FCR	3.111	3.083	0.014	0.225
Day 78 - 112				
ADG	850	831	15	0.428
ADFI	2,739	2,721	36	0.478
FCR	3.246	3.273	0.043	0.658
Overall				
ADG	815	795	15	0.094
ADFI	2,592	2,531	37	0.287
FCR	3.181	3.182	0.025	0.426

CD, corn-based diet; Non-GMO WD, non-genetically modified organism wheat-based diet; SEM, standard error of means; ADG, average daily gain; ADFI, average daily feed intake; FCR, feed conversion ratio.

Table 3. Effect of dietary non-GMO feed supplementation on nutrient digestibility in growing-finishing pig.

Items (%)	CD	Non-GMO WD	SEM	p-value
Day 27				
Dry matter	77.40	76.17	0.83	0.251
Nitrogen	77.07	76.04	0.80	0.290
Energy	77.63	76.50	0.82	0.288
Day 48				
Dry matter	75.75	74.07	0.83	0.194
Nitrogen	75.56	74.45	0.80	0.343
Energy	75.69	74.68	0.82	0.410
Day 118				
Dry matter	72.25	71.69	0.79	0.629
Nitrogen	71.65	69.93	1.14	0.322
Energy	72.27	71.50	0.78	0.511

CD, corn-based diet; Non-GMO WD, non-genetically modified organism wheat-based diet; SEM, standard error of means.

Blood lipid profile

Blood profiles was shown in Table 4. Non-GMO WD had no effects on protein, BUN, creatinine, and glucose except what BUN at d 21 on blood profile; however, the difference was not statistically significant. Thus, overall total blood profiles with WD and non-GMO WD treatments were found to be statistically insignificant.

Table 4. Effect of dietary non-GMO feed supplementation on blood profile in growing-finishing pig.

Items (mg/dL)	CD	Non-GMO WD	SEM	p-value
Day 21				
Protein	6.05	6.27	0.14	0.337
BUN	10.33	12.50	0.33	0.006
Creatinine	1.01	1.16	0.05	0.081
Glucose	88.50	87.33	0.88	0.393
Day 42				
Protein	6.38	6.50	0.11	0.493
BUN	11.00	13.17	0.80	0.115
Creatinine	1.00	1.17	0.06	0.122
Glucose	110.17	104.83	2.59	0.206
Day 77				
Protein (g/dL)	6.75	6.89	0.04	0.061
BUN	11.67	13.50	0.72	0.130
Creatinine	1.01	1.09	0.03	0.092
Glucose	108.00	106.33	1.73	0.526
Day 112				
Protein (g/dL)	6.84	6.94	0.07	0.395
BUN	11.83	13.67	0.80	0.168
Creatinine	1.03	1.10	0.04	0.237
Glucose	115.33	110.00	2.14	0.139

CD, corn-based diet; Non-GMO WD, non-genetically modified organism wheat-based diet; SEM, standard error of means; BUN, blood urea nitrogen.

Meat quality

The effects of dietary treatments on the meat quality are presented in Table 5, the meat quality parameters did not significantly differ among groups ($p > 0.05$). Thus, overall total meat quality with CD and non-GMO WD treatment were found to be statistically insignificant ($p > 0.05$).

Table 5. Effect of dietary non-GMO feed supplementation on meat quality in finishing pig.

Items	CD	Non-GMO WD	SEM	p-value
Meat color				
L^* (lightness)	59.36	59.24	0.24	0.744
a^* (redness)	16.85	16.70	0.07	0.242
b^* (yellowness)	6.17	6.19	0.29	0.973
Sensory evaluation				
Color	3.19	3.16	0.07	0.769
Firmness	3.31	3.13	0.02	0.391
Marbling	3.19	3.16	0.06	0.099
Cooking loss (%)	34.67	34.88	0.55	0.812
Drip loss (%)				
Day 1	7.50	7.60	0.23	0.799
Day 3	9.10	9.60	0.40	0.460
Day 5	15.40	15.60	0.36	0.681
Day 7	20.20	20.50	0.74	0.844
pH	5.39	5.42	0.04	0.663
Longissimus muscle (cm^2)	67.40	66.77	0.65	0.541
Water-holding capacity (%)	54.14	53.88	0.55	0.769

CD, corn-based diet; Non-GMO WD, non-genetically modified organism wheat-based diet; SEM, standard error of means.

Discussion

The main factor affecting the digestion and absorption of nutrients may be the content of non-starch polysaccharides (NSP) significantly higher than corn. Relevant studies have shown that the NSP and phytate are major anti-nutritional components in plant feed stuffs for non-ruminant animals (Woyengo and Nyachoti, 2011). On the other hand, others have reported that growing-finishing swine fed wheat tend to gain slower and have a lower average daily feed intake, but are more efficient than pigs fed a corn diet (Luce et al., 1996). The inconsistent results may be due to several factors such as stage of growth, diet complexity, type of wheat, health status of pig and other environmental or management factors. Moreover, introductions of wheat in broiler diets were shown to result in great variations in digestibilities (Maisonnier et al., 2001). It may be the difference in the digestive system between pigs and broilers. However, further investigation is warranted.

If protein intake is insufficient in an animal, the plasma protein concentration will be reduced (Min et al., 2009). In our study, no differences were observed in the concentration of protein in the blood of animals evaluated. This may have been because all of the pigs were provided with sufficient amounts of protein, regardless of the experimental diets they received. Plasma or blood urea N (BUN) concentration may be useful as an indicator of protein status within a group of animals as well as nitrogen utilization, and could help to fine-tune diets or identify problems with a feeding program (Whang et al., 2003). For example, milk urea N concentration is used to predict N excretion in dairy cows (Kohn et al., 2002). The difference in significance of BUN on d 21 may be due to the differences in the contents and types of corn and wheat proteins, and the values are within the normal range. Creatinine index also showed no significant difference. Non-GMO wheat-based diet showed comparable blood profile compared with corn-based diet.

Meat quality is one of the key indicators affecting the profitability of pig production, in addition to feed costs. Based on the results observed in our study, no significant difference was observed in meat quality parameters throughout the whole experiment. Owing to its low protein and high starch levels, wheat is mainly used as an energy source in the same way as corn (Carré et al., 2007). Currently, all research reports on wheat-based diets are concentrated on the addition and digestibility of enzymes; however, there were few reports about the effect of wheat diet on the quality of pork, and our findings warrant further investigation.

Conclusion

In conclusion, Non-GMO wheat-based diet did not have any adverse effect in growth performance, nutrient digestibility, blood profile and meat quality in Grower-Finisher pigs. Therefore, non-GMO wheat-based diet appears to be a viable possible alternative to corn-based diet in grower-finisher pigs.

Authors Information

Huan Wang, https://orcid.org/0000-0001-8955-7267

Dae-Won Kim, https://orcid.org/0000-0002-8778-1190

Jong Sang Yoo, https://orcid.org/0000-0002-1995-9858

In Ho Kim, https://orcid.org/0000-0001-6652-2504

References

AOAC (Association of Official Agricultural Chemistry). 2000. Official methods of analysis. 17th ed. AOAC, Gaithersburg, USA.

Bedford MR. 2000. Exogenous enzymes in monogastric nutrition - their current value and future benefits. Animal Feed Science & Technology 86:1-13.

Carré B, Mignongrasteau S, Péron A, Bastianelli HJD. 2007. Wheat value: Improvements by feed technology, plant breeding and animal genetics. World's Poultry Science Journal 63:585-596.

Hancock JD, Hines RH, Richert BT, Gugle TL. 1993. Extrusion of corn, sorghum, wheat, and barley affects growth performance and nutrient digestibility in finishing pigs. Journal of Animal Science 71:13.

Hanson BD, Mallory-Smith CA, Price WJ, Shafii B, Thill DC, Zemetra RS. 2005. Interspecific hybridization: Potential for movement of herbicide resistance from wheat to jointed goatgrass (*Aegilops cylindrica*). Weed Technology 19:674-682.

Honikel KO, Kim CJ, Hamm R, Roncales P. 1986. Sarcomere shortening of prerigor muscles and its influence on drip loss. Meat Science 16:267-282.

Kauffman RG, Eikelenboom G, Van der Wal PG, Merku G, Zaar M. 1986. The use of filter paper to estimate drip loss of porcine musculature. Meat Science 18:191-200.

Kohn RA, Kalscheur KF, Russek-Cohen E. 2002. Evaluation of models to estimate urinary nitrogen and expected milk urea nitrogen. Journal of Dairy Science 85:227-233.

Luce WG, Clutter AC, Maxwell CV, McPeake SR, Vencl R. 1996. Processing of wheat for growing-finishing swine. Oklahoma Agricultural Experiment Station. Animal Science Research Report P-951, Stillwater 280-284.

Maisonnier S, Gomez J, Carré B. 2001. Nutrient digestibility and intestinal viscosities in broiler chickens fed on wheat diets, as compared to maize diets with added guar gum. British Poultry Science 42:102-110.

Mavromichalis I, Hancock JD, Senne BW, Gugle TL, Kennedy GA, Hines RH, Wyatt CL. 2000. Enzyme supplementation and particle size of wheat in diets for nursery and finishing pigs. Journal of Animal Science 78:3086-3095.

Min BJ, Cho JH, Chen YJ, Kim HJ, Lee CY, Park BC, Lee JH, Kim IH. 2009. Effects of fermented soy protein on growth performance and blood protein contents in nursery pigs. Asian-Australasian Journal of Animal Sciences 22:1038-1042.

NRC (National Research Council). 2012. Nutrient requirement of pigs. 11th edn. NRC Academy Press, Washington D.C., USA.

NPPC (National Pork Producers Council). 2000. Pork composition and quality assessment procedures. NPPC Publication, Des Moines, USA.

Quist D, Chapela IH. 2001. Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. Nature 414:541.

Sullivan ZM, Honeyman MS, Gibson LR, Prusa KJ. 2007. Effects of triticale-based diets on finishing pig performance and pork quality in deep-bedded hoop barns. Meat Science 76:428-437.

Whang KY, Kim SW, Donovan SM, McKeith FK, Easter RA. 2003. Effects of protein deprivation on subsequent growth performance, gain of body components, and protein requirements in growing pigs. Journal of Animal Science 81:705-716.

Woyengo TA, Nyachoti CM. 2011. Review: Supplementation of phytase and carbohydrases to diets for poultry. Canadian Journal of Animal Science 91:177-192.

Yin J, Kim IH. 2019. Effects of multi-enzyme supplementation in a corn and soybean meal-based diet on growth performance, apparent digestibility, blood characteristics, fecal microbes and noxious gas emission in growing pigs. Korean Journal of Agricultural Science 46:1-10.